Evaluation of the ECHAM Boundary Layer Scheme against Large-Eddy Simulations

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Goal and Objectives
- Advance the understanding of the physical processes that determine the thermal and dynamical state of the cloud-topped boundary layer
- Evaluate and improve methods of representing shallow cloud systems in global climate models of the atmosphere
- Quantify improvement by comparing SCM diagnostics with similar diagnostics from detailed cloud systems realizations derived from LESs of FIRE and DYCOMS-II

Tool: Large-Eddy Simulation
- Only the important part of the turbulent motions is calculated
- The net effect of the small eddies is modeled by a subfilter model
- "Dissipate" energy
- Eddy-viscosity-mixing-length model

Strengths:
- Excellent tool for studying turbulence
- Generate database of PBL regimes

Tool: ECHAM
- ECHAM is an AGCM
- 19/40-level hybrid sigma-pressure coor.-sys.
- prognostic variables: vorticity, divergence, log of slp. Pressure, temperature, spec. humidity, liquid water content
- Relevant parameterizations:
  - TKE turbulence boundary-layer scheme
  - Cumulus convection is treated with bulk mass flux scheme
  - Relative humidity cloud scheme
  - Sundquist type large-scale precipitation formulation

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Stratocumulus clouds
- Marine stratocumulus clouds are
  - part of the general circulation
  - important modulators of the earth’s radiation budget
  - of importance to our understanding of the physics of the atmosphere

ECHAM-SCM with explicit entrainment parameterization: LWP vs. time
- SCM
- LES

Mean profiles of liquid water content $q$, simulated by different SCMs and LES (DYCOMS-II)
- Profiles averaged over (left) 3–4 and (right) 35–36 simulation hours, respectively

A new Boundary Layer Parameterization
- Permits realistic treatment of stratocumulus topped boundary layers with coarse vertical resolution
- It combines:
  - 1.5 order TKE closure using Bougeault-Lacarrere length scale
  - Explicit entrainment closure at boundary layer top
- Technical implementation of entrainment closure requires:
  - Numerical method for computing propagating phase boundaries
  - Approach permits the stratocumulus top to lie between grid levels and continuously evolving with time

A computational method for propagating phase boundaries
- Shift grid points locally to locally nonuniform grid due to two cells moving
- $X_{cell}$ represents position of moving phase boundary
- Subsequently locations of $X_{cell}$ will change as function of time
- When one cell is too small, we adjust the location of one grid point

LES-Results
- Diurnal variation of LWP (FIRE)

Variances and fluxes (FIRE)
- Profiles represent one-hour average between 23 h < t < 24 h (nighttime, top) and 36 h < t < 37 h (daytime, bottom)